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NAS9-150

May 1, 1965

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Report Period
March 16 to April 15, 1965

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Contractually required monthly report

ABSTRACT

Brief, illustrated narrative report of Apollo Program progress for the period, highlighting accomplishments, milestone achievements, and a continuing summary of the Program.

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PROGRAM MANAGEMENT

STATUS SUMMARY

The Apollo boilerplate 22 service module was shipped to the White Sands Missile Range March 16, and the command module, launch escape subsystem, boost protective cover, and all loose equipment were shipped March 17, in support of the scheduled shipment dates (see Figure 1, page 23).

DITMCO operations for the service module and launch escape tower of spacecraft 009 were completed on March 18. With this accomplishment, the installation of service module subsystems required for power-on testing was complete. Final NASA structural inspection of the service module was completed on March 23, and power-on testing began March 24. Initial power-on testing was successfully completed on March 27.

The wire harness installations in the forward crew compartment for the command module of spacecraft 009 were completed and accepted by NASA on March 23. DITMCO operations for these wire harnesses and for the launch escape motor wire harnesses were completed on March 24 (see Figures 2 and 3, pages 24 and 25).

Installation of the partial subsystems, required for spacecraft 006 service module quality verification vibration testing (QVVT), was completed on March 22. QVVT began on March 24 and was completed on April 6. Installation of simulated mass assemblies for the command module of spacecraft 006 was completed on April 1, and testing began April 8. Spacecraft 006 QVVT operations were completed April 15 (see Figure 4, page 26).

The service module of spacecraft 007 was completed structurally and accepted by NASA on March 24. The service module was transferred to Apollo Engineering for instrumentation installations. These operations were completed, and the service module was delivered to the NAA Los Angeles Division on April 14 for acoustical testing.

Primary bonding operations and the bonding of honeycomb core and face sheets to the forward inner crew compartment of spacecraft 007 were completed on April 7.

Structural assembly operations for the command module of spacecraft 002 were completed on March 31.

Inner structure welding operations, joining the forward and aft inner structure sections of the command module of spacecraft 004, were completed on March 30.

All four heat shields for the command module of spacecraft 008 were shipped to Avco on March 29 for application of ablative material.

Spacecraft 020, last of the Block I spacecraft, is in primary structural bonding in Manufacturing, and Block II long-lead time tooling and detail fabrication are in progress to support schedule requirements.

ASSOCIATE CONTRACTOR ADMINISTRATION

An agreement specifying spacecraft test interface requirements between NASA, S&ID, and GE has been signed and implemented by all parties. This agreement specifies the procedures and methods to be used among the contractors in conducting spacecraft testing at Downey.

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DEVELOPMENT

SYSTEM DYNAMICS

Aerodynamics

The FS-2 static stability wind tunnel test of the Block II command module and the launch escape vehicle and canards was started on March 5. The test is being conducted on two configurations, one with the command module alone and the other with the command module and the launch escape tower mated. Preliminary load estimates for the two configurations have been transmitted to Ames Research Center in support of this test.

Pyrotechnics and Earth Landing Subsystem (ELS)

The boilerplate 22 mission sequencer flight unit satisfactorily completed final functional and acceptance tests and was delivered to WSMR on March 31.

The qualification drop test program of the earth landing subsystem has been delayed as a result of the grounding of all C-133 aircraft by the Air Force. If the restriction continues for any length of time, the fulfillment of the constraint drop test requirements for such vehicles as boilerplate 22, spacecraft 002, and spacecraft 009 will be in jeopardy.

The first of a series of underwater tests has been completed on the main parachute guillotine disconnect. Four specimens were fired at a depth of 2. 5 feet, and each successfully severed the required five plies of a 10, 000-pound nylon webbing as well as the two plies of 2500-pound nylon webbing. These tests were part of a series designed to obtain information relative to the optimum pyrotechnic charge required to perform this function. The next series of tests will be conducted at a depth of 10 feet.

Boilerplate 1 water impact drop tests 94 and 95 were completed during this report period. The purpose of these tests was to determine peak design pressures when impact occurs at severe command module tip-over conditions, and to provide full-scale data for comparison with the tenth-scale data that have been used for structural impact design. For test 95, a simulated uprighting air bag canister was added in the appropriate position, and pressure on the canister was measured. Preliminary analysis of both tests indicates that good agreement exists between tenth-scale data and full-scale data, so that side wall and tunnel design pressures established by the tenth-scale data need not be changed.

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MISSION DESIGN

More than two years of study of spacecraft attitude and the solution of attitude-related problems have resulted in some significant conclusions relative to the coordinate systems used to describe the pointing of the spacecraft. The study indicated a need to limit the number of different systems and to promote consistency throughout the participating agencies in the Apollo Program. It was found that basically different coordinate needs exist for system analysis, in which considerations of ephemeris, sun and shade, and various line-of-sight geometries exist, and for operations analysis where coordinates used in pilot displays are of primary importance. The types of coordinates used to express future attitude sequences will be as follows:

1. Sun direction angles

2. Manned space flight network direction angles in body $\theta \phi$ coordinates

3. Slope and heading of body axes with respect to the trajectory plane and earth or moon vertical

4. Body axes right ascensions and declinations

5. Right ascension and declination of stable platform axes

6. Euler angles (relative to the platform) of the spacecraft body axes

A problem area exists, in that many of the platform alignments must be made in directions dictated by random variables and cannot be predicted in advance of flight. S&ID has tentatively adopted a format standardizing the random attitude events for presentation of future attitude timelines. Modifications in computer programs are now under way to incorporate attitude calculations in the preceding coordinate systems.

The capability to generate a timeline of physical events was incorporated into the Precision Trajectory IBM Computer Program AP110. The following physical events and associated data are available in tabulated printout form and on binary tape:

1. The time and slant range associated with the gain and loss of line of sight to individual tracking stations for masks of zero and 5 degrees

2. The times at which the center of the sun and the center of the moon rise and set

[redacted]

3. The times at which the upper limb of the sun and the upper limb of the moon rise and set

4. The times of dayward and nightward terminator crossings

5. The times of ascending and descending crossings of the earth equator

6. The time of crossing the Cape Kennedy meridian

In addition, special printouts (not required on binary tapes) give the following information at each nodal crossing:

1. Right ascension and geographic longitude of the ascending node

2. Argument of perifocus

3. Orbit plane inclination to the true equator of date

4. Sun, moon, and vernal equinox directions in an orbit plane reference system

A study has been completed on service module reaction control subsystem (RCS) ejection from orbit for Block I missions. RCS propellant reserve requirements and heating load considerations during the entry flight phase were investigated for ejection from elliptical orbit, orbit apogee, and circular orbits. Ejection ΔV requirements were minimized by considering only ejection to the overshoot conic (3500 NM entry range), since the ejection ΔV requirements become greater for steeper penetration angles.

Two basic entry flights were considered in the analysis, consisting of entry with a roll attitude of zero degrees or 180 degrees followed, in each instance, by the initiation of a constant roll-rate of 14 degrees per second at the entry threshold (g = -0.05). Consideration was also given to a modification of the 180-degree entry by delaying the initiation of the roll-in mode to a g-level of 1.0 to allow shallower penetration angles and thus less ejection ΔV requirements. It should be noted that the delayed roll-in mode would require the addition of an accelerometer to allow pilot monitoring of the g-level.

A comparison of the minimum RCS ejection ΔV requirements and corresponding RCS propellant reserve is given in Table 1 for the three flight modes described. Propellant quantities given in parentheses are required values, including attitude control based upon an 85 percent efficiency factor. The comparison is given for long-duration orbits

[redacted]

corresponding to 140-NM circular orbit and 105/180-NM elliptical orbit. The 140-NM circular orbit corresponds to the NASA-specified long-duration mission of approximately 18 days, and the 105/180 NM elliptical orbit corresponds to a 14-day perigee decay to 400, 000 feet in an atmosphere which is 100 percent more dense than the 1962 U. S. standard. Propellant weights are based upon a 23, 000-pound payload in orbit at the time of ejection.

Table 1. Minimum RCS Ejection ΔV Requirements and Corresponding RCS Propellant Reserve

Orbit (NM)	Entry Mode	Ejection ΔV (fps)	RCS Propellant (lb)	Maximum Total Heat Load (Btu/ft^2)
140 Circular	$\phi_{EN} = 0°$	178	467 (550)*	32, 700
105/180 Elliptical	$\dot{\phi}_{0.05\,g} = 14°/sec$	111.6 Apogee	292 (344)*	33, 950
140 Circular	$\phi_{EN} = 180°$	171	450 (530)*	31, 820
105/180 Elliptical	$\dot{\phi}_{0.05\,g} = 14°/sec$	105 Apogee	275 (324)*	33, 000
140 Circular	Delayed roll-in $\phi_{EN} = 180°$	169	442 (520)*	29, 000
105/180 Elliptical	$\dot{\phi}_{1.0\,g} = 14°/sec$ (accel. addition)	103 Apogee	267 (314)*	30, 050

*Includes attitude control propellants

The minimum ΔV requirement with current spacecraft subsystems ($\phi_{EN} = 180°$, $\dot{\phi}_{0.05\,g} = 14°/sec$) is 105 fps for ejection from apogee of the 105/180-NM elliptical orbit, requiring an RCS propellant reserve of 324 pounds (85 percent efficiency factor). The addition of an accelerometer to delay the roll initiation to the 1. 0-g level reduces the propellant reserve 10 pounds and the total entry heating load approximately 9 percent. Delaying the roll-in mode to higher values of g results in no significant decrease in the ΔV requirements. Additional reductions in RCS propellant reserve requirements for orbit ejection may be obtained by considering the use of orbit-sustaining techniques. Investigation of these techniques (which involve

[redacted]

a trade-off of orbit design, RCS propellant required for orbit ejection, and ullage maneuvers), may provide a substantial increase in mission duration and/or maneuver flexibility.

The implementation of increased lunar excursion module weight and map and survey equipment in service module sector I requires a reduction in SPS propellant weight to maintain the maximum spacecraft payload weight allotment. Since reduced propellant weight results in reduced mission ΔV capability, new service propulsion subsystem (SPS) ΔV budgets have been determined which are consistent with the SPS propellant weights allocated.

To prevent a significant reduction in reliability values for mission success and crew safety, the new ΔV budgets maintain previously assigned values for midcourse corrections and lunar excursion module rescue. This, therefore, does not impose more severe subsystem design requirements for the primary or backup navigation and guidance subsystem. The basic reduction in ΔV has been absorbed in lunar orbit insertion and transearth injection maneuvers. For spacecraft configurations without map and survey, a free-return translunar trajectory has been selected; with map and survey, however, a non-free return translunar trajectory must be imposed.

Table 2 indicates the required ΔV reductions from the NASA design ΔV budget for the two configurations considered.

Table 2. Required ΔV Reduction

Maneuver	ΔV Reduction (fps)	
	No Map and Survey, Free Return	With Map and Survey, Non-Free Return
Lunar orbit insertion	-150	-430
Transearth injection	-120	-60

The reduction in mission ΔV capability, in general, results in less lunar landing site area capability and/or less percent of the month mission capability. A cursory examination of the mission capability available for equatorial lunar landing sites yields almost 100 percent of the month capability for both the free-return trajectory (no map and survey) and the non-free return trajectory (with map and survey). Judicious selection of optimum mission dates (i.e., periods when ΔV's are minimized) could allow performance, over reasonable time spans, of lunar landing missions at lunar sites within the area bounded by ±5 degrees latitude and ±45 degrees longitude.

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CREW SUBSYSTEMS

The third zero-gravity evaluation involving the waste management subsystem was conducted in mid-March at Wright-Patterson Air Force Base. Of primary concern was the employment of a directed air jet located at the top of the fecal canister to disengage and/or deflect the fecal matter into the canister under zero-gravity conditions. Preliminary analysis of the results of this evaluation indicate a requirement for such an air jet in the Apollo waste management subsystem.

During the waste management evaluation, the first zero-gravity liquid dumping operating using the Apollo urine dump lock was performed. The liquid dumping operation was successful, and approximately 788 grams of liquid were evacuated from the lock under zero-gravity conditions.

Three storable tubular extendible members provided by DeHavilland were evaluated for extravehicular transfer concept feasibility. A hook attachment was successfully made by a subject in a pressurized Apollo space suit with a portable life-support subsystem and external thermal garment. The extendible device used for the hook attachment was a 20-foot long, 1-inch diameter tube with a birch plywood hook. The hook was attached to an 18-by-12-inch bail. The ease of boom maneuvering and hooking of the bail indicates no problem of operation with a full-length boom.

Initial acoustic tests on boilerplate 14 were completed on March 17 with astronaut Dick Gordon participating. Noise levels produced inside the capsule were measured for each subsystem separately as well as for combined subsystems. Influence of equipment noise on voice transmission and receiving and warning tone reception was also determined. Reduction of data is in process.

The training portion of Phase 2, Apollo event sequence panel evaluation, has been started. Phase 2 investigations include determination of the effects of certain types of digital event timer malfunction and the utility of various alternate timing methods. Training for two pilot subjects has been initiated.

An investigation was completed to determine if the Gemini glove fingertip lights would be compatible with Apollo recessed rotary selector switches and semirecessed toggle switches. Analysis of preliminary results indicated that there was no serious interference.

STRUCTURES

The 40-inch diameter SPS qualification test tank 6 successfully completed test cycling in mid-March. The vessel subsequently passed X-ray

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tests, fluorescent penetrant inspection, and leak check. It is now undergoing creep test. The burst test following will be the last before qualification.

The first-stage primary bond of the inner structure forward assemblies of spacecraft 012 was completed using the new double bagging technique. Results were encouraging, and it appears that mold line contours will be considerably better than previous assemblies (see Figure 5, page 27). All bonding of honeycomb core to inner skin was completed in a single cure with no significant discrepancies. The base of the forward section was held on a rigid tooling ring while inner and outer vacuum bags with caul plates were used to maintain structural contour.

FLIGHT CONTROL SUBSYSTEM

Flight Subsystem

Results of preliminary analysis indicate that passive thermal control can be achieved without requiring the primary or the secondary attitude control subsystem to be in operation. The spacecraft X-body axis can be held within a circular cone of 20 degrees half-angle by spinning the spacecraft at a rate not greater than 2.5 revolutions per hour. This requires an operational procedure to align the resultant angular momentum vector perpendicular to the sun line prior to each spin maneuver. The total service module reaction control subsystem (RCS) propellant required to start and to stop the 2.5-revolution per hour spin six times during the lunar orbital rendezvous mission is 0.84 pounds.

The final phase of the study to determine the transearth midcourse thrust pointing accuracy requirement (Block II) has been completed. The study indicates that the total pointing accuracy can be relaxed to 1.5 arc degrees rms. This change permits a reduction in the thrust vector control accuracy requirement from 0.67 to 0.83 arc degrees rms, thereby increasing the probability of reduced fuel consumption.

The service module RCS propellant requirements for the proposed Block II design reference mission (for the Command and Service Module Technical Specification [Block II] SID 64-1344) have been modified to reflect the change of the SPS propellant settling maneuver requirement. This most recent propellant settling maneuver affects basically the lunar orbit phase and changes the ullage maneuvering time from 5 seconds to an average of 12 seconds of 4-jet firing. This change increases the total propellant requirement from 735 to 780 pounds. (Maximum usable tank capacity is 790 pounds total.)

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Automated Control

The prequalification confidence tests on the Lockheed Timer have been completed at Autonetics. The timer was subjected to four environments in the following order: acceleration (25 g's), oxidation, vibration, and shock. Functional tests were performed before, during, and after each environment. Preliminary analysis of the test data indicates no apparent problem areas.

The first phase of the spacecraft 009 combined-subsystems dynamic verification study has been completed. Approximately 60 post-checkout computer runs were successfully completed. Preparation for the second phase of the study, using more sophisticated subsystem components, is in progress.

TELECOMMUNICATIONS

Instrumentation

Rework of the inaccessible instrumentation installations in the aft heat shield bondline of spacecraft 009 has been completed, and the shield has been shipped to Avco for ablator processing.

All instrumentation checkout specifications required for spacecraft 009 have been completed and released.

The procedure for failure mode and effects analysis for instrumentation subsystems has been established. The analysis of spacecraft 009 is complete and is now in progress for spacecraft 011.

Firm and complete measurement requirement lists for spacecraft 017 and 020 have been advance-released.

ENVIRONMENT CONTROL

A production environmental control subsystem (ECS) radiator configuration for Block II was established with Ling-Temco-Vought in mid-March. The radiator panels will be circumferential in design with 12 tube passages 165 inches long spaced 5 inches apart. A meeting was held with Olin Mathieson and Reynolds in Tulsa to acquaint the S&ID Tulsa manufacturing personnel with details of radiator development history. The final finishing and bonding of the honeycomb and radiators will be done by the S&ID Tulsa facility.

Discussions were held to resolve the location of the lunar excursion module pressurization valve to conserve space on the command module

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control panel as well as to save the astronaut an extra operation. It was decided to eliminate the position from the valve that controlled the vent between the drogue chute compartment and the tunnel. A pyro-valve tied into one of the sequencing circuits will fire just prior to impact, thus closing the vent and preventing water from entering the capsule. Other locations for the lunar excursion module pressurization valve, now less critical, are under study.

Silicone oil has been proposed as a substitute test fluid in place of water-glycol for the initial checkout of the environmental control unit. The oil will prevent possible corrosion in the unit and can be replaced by water-glycol when the vehicle is on the pad.

The cabin air temperature of the Block II spacecraft has been determined for average ablator bondline temperatures with the cabin heat exchanger set to full heating. External temperatures analyzed were from -150 F to zero F. The ECS was able to maintain air temperature between 70 F and 80 F under all conditions.

The cabin atmosphere analyzer has been in continuous operation for 25 days. During this continuous operation, approximately 400 standard gas samples containing known concentration of H_2, N_2, CO, CO_2, and CH_4 have been analyzed by the process gas chromatograph. The analyzer is operating satisfactorily and meets the test sensitivity and reliability requirements at atmospheric test pressure.

Radiation effects on the high-gain antenna earth sensor have been reevaluated using proton and alpha model design events. Doses and emergent fluxes inside the infrared sensor package at a typical electronic component location were individually computed for protons and alpha particles using solid-angle geometry and the primary proton and alpha dose codes. These levels will be used in selection of radiation-resistant components.

Revised designs of the graphite flight test pressure sensors and flight test calorimeters were tested at Ames. Data from these tests resulted in further redesign of the flight test calorimeters and pressure ports. The redesigned sensors appear to be compatible with the heat shield material, but the calorimeters will require further development and testing. Pressure orifices drilled in ablator material caused no serious erosion effects on the material, and measured pressures remained predictable for the duration of the run. This is in contrast to the protuberance effect exhibited by the original design graphite pressure taps in a previous run.

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ELECTRICAL POWER

Preliminary data from testing by Beech Aircraft of a cryogenic hydrogen tank indicates that the high-pressure fill concept resulted in an increase in stored hydrogen of two pounds per tank.

A plan of action has been formulated to install the spacecraft 006 inert cryogenic storage tanks in spacecraft 001 during the April down-time. The purpose of using these tanks in spacecraft 001 is to gain preliminary structural dynamic data on the cryogenic gas storage tanks before cryogenic servicing of the actual spacecraft 001 storage tanks.

Since the last report period, one of the two fuel cell qualification power plants for this phase of the qualification test failed at 138 hours of load time. Investigation into the cause of the failure is continuing with no definite cause having been identified at this time, although some unusual reactant tube plugging has been established. The second power plant will complete the 400-hour load schedule on April 19.

An auxiliary battery subsystem has been designed for spacecraft 011 and subsequent Block I unmanned spacecraft. Three 40-ampere-hour batteries, with a control subsystem operated by the mission control programmer, will be added in the command module to supply the programmer and instrumentation loads from isolated buses.

Qualification tests were completed on the pyrotechnic battery. However, the test data indicate that the battery is adversely affected by wet stand-time. This design deficiency caused three different types of battery failure during the qualification test. The cause of failures has been determined, and further corrective action cell tests are being run. The resulting data are being analyzed prior to directing the supplier to begin battery qualification retest.

The fuel cell motor switch failed the electromagnetic interference (EMI) tests during qualification. A redesign analysis to eliminate the EMI problem in the sensing circuit of the switch is now in progress at the supplier.

PROPULSION

Service Propulsion Subsystem (SPS)

The SPS has been installed in the service module of spacecraft 009 and is undergoing checkout.

Air period 7 of the AEDC Phase II test program was completed. A total of 19 tests (439.4 seconds) were accomplished on engine 011. Injector 046, installed on engine 011, is the first of five baffle injectors fired at AEDC.

A total of 71 injector and 65 engine firings were completed at Aerojet General.

Engine 040, using a pneumatic valve actuation subsystem, was fired during this report period. Twenty-nine tests (615.4 seconds) were successfully completed.

Test Series I on spacecraft 001 was completed at WSMR-PSDF on March 27. Test Series II on test fixture F-2 was completed at WSMR-PSDF on March 23. Vehicle and facility updating in progress consists of gimbal subsystem activation, baffled injector installation, and pneumatic engine propellant valve installation.

Reaction Control Subsystems (RCS)

Qualification testing of the command module RCS engine nozzle extensions was started on March 19 at Rocketdyne.

Four service module RCS engines were delivered on March 24, completing the engine requirements for spacecraft 009. The second of three service module RCS engines undergoing preflight rating tests at Marquardt has successfully completed acceptance and salt fog exposure tests.

In view of interface problems encountered during the acceptance testing of the RCS fuel quantity sensors at Giannini for spacecraft 001, it was considered advisable to subject the spacecraft 009 service module gauging subsystem components (excluding the display panel) to integrated system acceptance testing prior to delivery rather than on the basis of individual units as previously planned. The first deliverable spacecraft subsystem was shipped from Giannini on April 8.

Launch Escape Subsystem (LES)

Thiokol has been conducting a fault isolation test to duplicate the tower jettison motor ignition delay that occurred on February 2. Results appear to support the contention that the booster powder in the February 2 delay could have been pistoned from the igniter cartridge before it ignited.

In accordance with NASA redirection, the tower jettison motor qualification test was resumed on March 25. Performance was normal.

Launch escape, pitch control, and tower jettison motors for boilerplates 22 and 23A have been delivered to WSMR; grain inspection of the launch escape motors has been completed; and the motors have been assembled into launch escape subsystem stacks for use.

Propulsion Analysis

A subsystem description has been released for the service module RCS heaters for Block I vehicles. The subsystem utilizes one 36-watt heater per quad with thermostat control (75 to 100 F). The estimated maximum energy requirement (no vehicle orientation constraints required) for the heaters in earth orbit is 2.6 killowatt-hours per day. The command module displays and controls required to monitor the subsystem operation have been determined.

Analysis shows that the allowable usable propellant for the service module RCS for missions 201 and 202 must be reduced from 790 to 732 pounds. This reduction results from an increase in engine specification mixture ratio tolerance and the mixture ratio shift during the pulse mode.

GROUND SUPPORT EQUIPMENT (GSE)

The acceptance checkout equipment (ACE) models for spacecraft 009 have been accepted by NASA on interim DD 250's. A task team effort has begun a study to achieve an optimum design for suspending ACE carry-on from the crew couches.

Some engineering and manufacturing problems have arisen in the cleaning positioner test program. These problems resulted from increased weights of the spacecraft command module and service module, new NASA proof-load requirements of 2 g upright and upside down, and certain spacecraft interferences. Results of a study of these problems indicate that the existing cleaning positioner configuration is still adequate for the increased weights except for minor redesign required to eliminate interferences. The cleaning positioner with command module mock-up is shown in Figure 6 (page 28).

A review of Block II minimum GSE requirements was completed with NASA March 23 and 24, and an agreement on a baseline list was achieved.

RELIABILITY

Audits of 19 subcontractor-supplier Apollo reliability programs were conducted during this report period. Audit reports and recommendations for correction of deficiencies are in process.

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At a joint NASA-NAA meeting held to revise the Test Requirements Report, SID 65-120, clarification was made of the vibration requirements rationale, the electrical and plumbing test evaluation, and the explosive valve qualification program. The changes in test requirements were documented in a summary report. The most significant changes are in the area of vibration rationale and explosive valve testing. The explosive valve test program as modified indicates that a supplemental test program is required to determine operation characteristics and design margins, and that ten additional samples are required for engineering tests.

A reliability evaluation was conducted to determine the effect of a change in launch escape motor backup capability on mission success reliability. Employment of the launch escape motor as backup to the tower jettison motor when the motor fails to ignite, or when the motor ignites but explodes prior to tower separation from the command module, has been considered a means of continuing a lunar mission in the event of a motor failure. Because the boost protective cover cannot be shown to furnish adequate protection for the command module during launch escape motor ignition, consideration is being given to providing the launch escape motor as backup to the tower jettison motor only, for safe recovery of the crew during an abort.

The present mission losses, based on the mission continuation backup capability of the launch escape motor, is 30 per million missions. The changes in backup mode utilization will result in an increase of 24 mission losses or a total of 54 losses per million missions, and does not significantly affect the overall mission success objective for the lunar mission.

A study was made of the impact on crew safety caused by the boost protective cover particles striking and damaging specific equipment of the launch escape subsystem (LES) during various abort modes. The probability of critical damage was found to be no greater than 2 per million missions; this is considered compatible with the overall Apollo crew safety goal. This result is based on the summation for all abort altitudes up to LES jettison of the probabilities of abort, hit, and damage during specific altitude intervals.

SPACECRAFT DEVELOPMENT ANALYSIS AND INTEGRATION

At a meeting with NASA, it was decided that the test plan for spacecraft 001 should be revised to reduce the amount of detail and to issue Apollo Test Requirements (ATR) providing test details, thus reducing the need for frequent, extensive changes in the test plan. Subsequently, the initial spacecraft 001 ATR's were released defining details of test series 1, and the ATR for series 2 tests was completed. A new integrated test schedule was also established at the meeting.

The Ground Operations Requirements Plan (GORP) for spacecraft 011, SID 64-2114-2, was completed and distributed on April 5. This document is written as a deviation from the basic Block I GORP, SID 65-301, published in March. The Block I GORP delineates the checkout requirements, sequences, and equipment for conducting the prelaunch tests and preparation of Block I spacecraft from factory to liftoff. The spacecraft 011 GORP shows only those operations in which spacecraft 011 differs from the basic Block I vehicle.

The abort criteria package for spacecraft 009 has been compiled for incorporation in the spacecraft 009 vehicle test plan. In this package, each major spacecraft subsystem has been evaluated in terms of identifiable failure modes, effects of failures or malfunctions on functionally related assemblies, tolerance limits for real-time displayed system performance parameters, recommended action in the event of malfunction, etc.

Because of the nature of the spacecraft 009 mission (i. e., unmanned and suborbital), the actual conditions requiring abort are few. However, the detailed subsystem breakdown presented in this document will apply directly to later manned missions wherein spacecraft subsystem performance degradations will play a major role in making abort decisions. Flight operations and flight crew personnel will be guided by these criteria in the control and abort decisions of each mission, as well as in the preparation of training manuals.

OPERATIONS

DOWNEY

Boilerplate 14

Electrical power subsystem off-normal testing of boilerplate 14, begun after completion of the acoustic test, was continued through March 26; further testing, however, was delayed to prepare boilerplate 14 for the spacecraft 009 mission simulation. Concurrently, preparations for testing the ACE carry-on equipment outside the vehicle were accomplished, and the test was completed on April 13. Test results indicated that the ACE carry-on equipment could be located outside the vehicle without apparent detrimental effects arising from the use of longer interconnecting cables.

The first dry run of the spacecraft 009 mission simulation test using boilerplate 14 was completed on April 12. NASA acceptance checkout engineers were on station for familiarization. The second dry run of the simulation test was completed on April 13. Spacecraft 009 mission simulation test using boilerplate 14 was started on April 14 and is in progress.

Spacecraft 006

Twenty-one QVVT test runs were accomplished at a vibration amplitude level from 0. 25 g to 1. 5 g and at a frequency range from 20 to 2000 cps. Following test run 21, the service module was removed from the QVVT equipment and returned to manufacturing. The command module was installed on the QVVT equipment. Fifteen vibration test runs were conducted with sine, random, and shaped random vibration inputs at magnitude levels from 0. 5 to 1. 5 g over a frequency range of 20 to 2000 cps.

The decibel level at the thrusters was 110 decibels; however, the sound pressure level decreased to 92 decibels at a distance of 30 feet from the thrusters. QVVT with the spacecraft 006 service module and command module verified the capability of the Ling equipment to vibrate spacecraft modules as required and the ability of the monitor and control equipment to function as designed.

Spacecraft 009

The power distribution check with the spacecraft 009 service module was accomplished. Installation and fit check of the service propulsion subsystem heat shield was completed, and the heat shield was removed. Some interference between the heat shield and service propulsion engine lines was encountered, and the lines were rerouted.

The spacecraft 009 service module was moved to the high-pressure test area (see Figures 7 and 8, pages 29 and 30) on April 4 for service propulsion subsystem proof pressure and leak tests. On April 12 the service module was moved to the pressure test area where the service propulsion subsystem proof pressure and leak tests were started.

WHITE SANDS MISSILE RANGE (WSMR)

Propulsion System Development Facility (PSDF)

Test Fixture F-2

The test requirements for tests 6 and 7 of test series 2 were revised to accomplish hot-firing tests while awaiting delivery of hardware required for the cold gimballing tests. Tests 6 and 7 were accomplished on March 23. A hold was required between firings 4 and 5 of test 6 for a visual inspection following an after fire that resulted from combustion of residual propellants from the engine feed lines. No damage was sustained, and the test was completed satisfactorily. Test 7 was completed as scheduled. All monitored system operating parameters indicated nominal performance during both tests.

Test 7 completed test series 2; the test fixture F-2 and associated GSE then entered a lay-up period for engine gimballing modification, reaction control subsystem cross-patching, and accelerometer installation for frequency response tests. Updating of the test fixture and GSE is continuing on schedule.

Spacecraft 001

Three tests (3, 4, and 5) were conducted with the spacecraft 001 service module during this period to complete test series 1. The test series was conducted to establish normal operation of the service propulsion subsystem in spacecraft 001; to evaluate system operational characteristics during transients resulting from changes in propellant levels, propellant tank transfers, and engine restarts; to determine helium subsystem compatibility; and to evaluate system operation for steady-state and transient conditions during single propellant valve bank operations. The individual test operations were conducted satisfactorily, and data recorded during each test operation indicated that all subsystems operated normally. The total engine firing time after completion of test series 1 was 765 seconds.

The rough combustion accelerometer range was reevaluated because of rough combustion cutoffs encountered during prior testing. The limits were determined to be too severe and were increased from 120 g's and 40 milliseconds time delay to 180 g's and 60 milliseconds. A rough combustion cutoff was experienced again on the first firing of test 3; post-test analysis, however, revealed that this rough combustion cutoff occurred at 135 g's because of an improper setting of the rough combustion cutoff device. The device was reset to the proper limits, and rough combustion cutoff was not experienced on test 4 or 5.

Test stand 2, spacecraft 001, and associated GSE have entered a short lay-up period for gimballing modifications and installations prior to initiation of test series 2.

Mission Abort

Boilerplate 22

After arrival at WSMR, the service module of boilerplate 22 was placed in storage until April 1, when the service module was moved to the pad and mechanically mated to the Little Joe II launch vehicle. Alignment of the service module on the Little Joe II was completed on April 14.

The command module, associated GSE, and loose equipment were transported to the vertical assembly building. The receiving inspection was completed and the command module was installed on the weight and balance fixture. The horizontal weight and balance of the launch escape subsystem (LES) and the command module were accomplished. The command module parachute subsystem, initially installed on March 27, was removed because of a reefing cutter problem. Replacement parachutes were received and installed, followed by installation of the drogue parachute, pilot chute mortars, and harness. Single-point and vertical weight and balance of the command module were completed April 7.

The LES and hard boost protective cover were mated to the command module, and thrust vector alignment was accomplished. The LES was demated, and the command module was moved to the pad and stacked on April 15. All operations are on schedule.

FLORIDA FACILITY

Boilerplate 26

Boilerplate 26 LES buildup was completed on March 17. The LES total weight and center-of-gravity determination was completed on March 19; then the LES was stored with the spacecraft sling attached.

The instrumented service module reaction control subsystem (RCS) engine quad A arrived on March 29. The silicone rubber compound that coated each thermocouple was removed to prevent receipt of erroneous temperature readings during the boost phase of flight.

The service module and service module adapter of boilerplate 26 were delivered by air from Marshall Space Flight Center to the eastern test range on April 10. NASA released the service module to S&ID on April 12 for the command module-service module fit check and installation of the instrumented RCS engine quad. The command module-service module fit check was accomplished successfully on April 15.

FACILITIES

INTEGRATION AND CHECKOUT FACILITY

Monitoring and Control Subsystem

Phase A of the engineering plan for the monitoring and control subsystem for QVVT has been received and approved. The builder has started the procurement of long-lead time items and has started detailed engineering design for the subsystem. Delivery of the subsystem to S&ID is scheduled for May 18, 1965, with contract completion scheduled for May 28, 1965.

ENGINEERING ADMINISTRATION BUILDING

The lessor completed all of the required building work with the exception of the exterior, parking lot, and punch list items on April 15. S&ID has accepted the building.

Fluid Distribution Subsystem, Bench Maintenance Equipment, Integration and Checkout Facility

The contractor began installation of the fluid distribution subsystem on March 30, 1965, and installation is scheduled for completion by May 14, 1965. Site Activation has determined that the fluid subsystem in the BME area is not needed to support spacecraft 009. First usage will be in support of spacecraft 011 approximately July 2, 1965.

APPENDIX A

ILLUSTRATIONS

Figure 1. Boilerplate 22 Command Module in Vertical Assembly Building, White Sands Missile Range

7008-86-203A

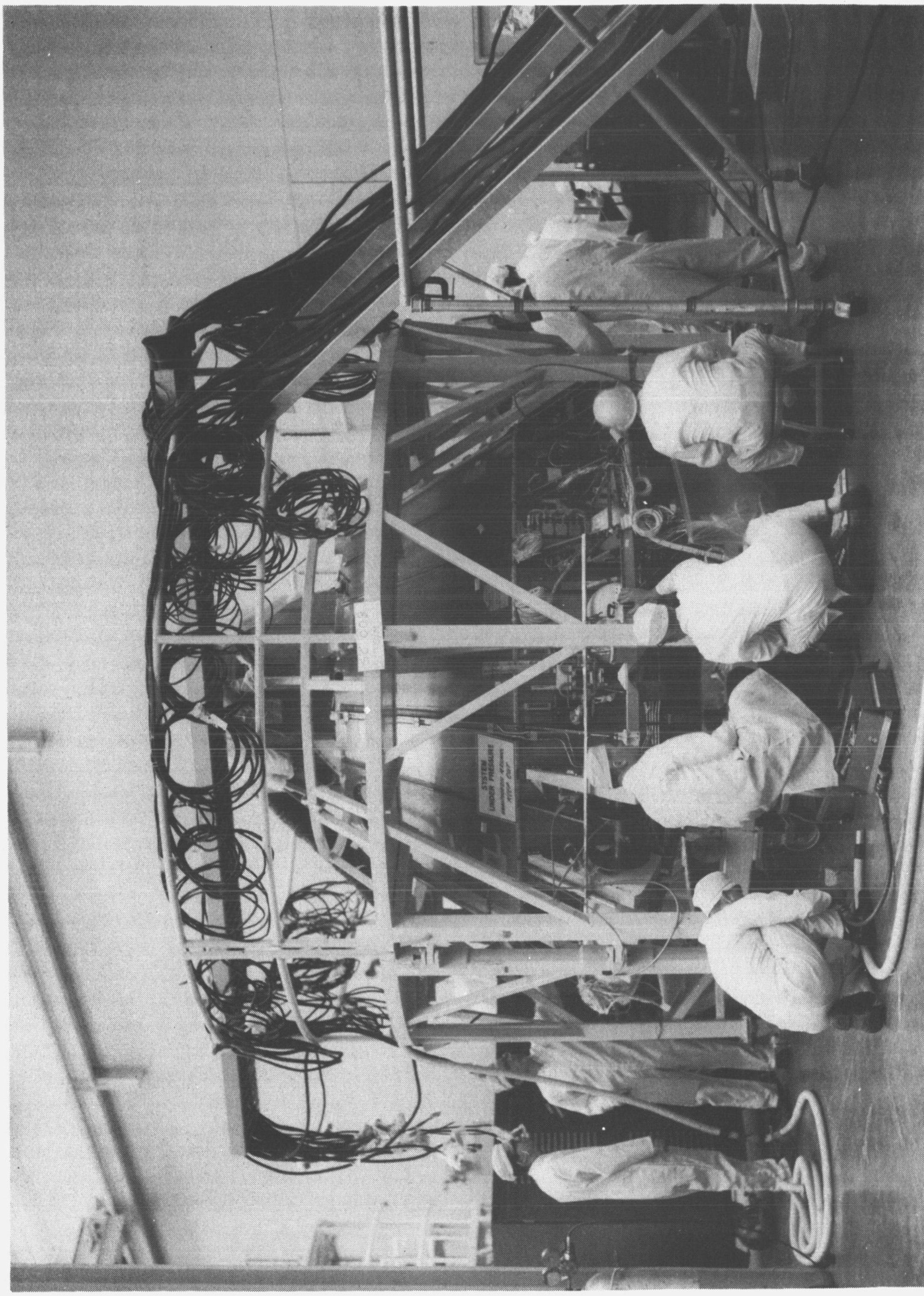
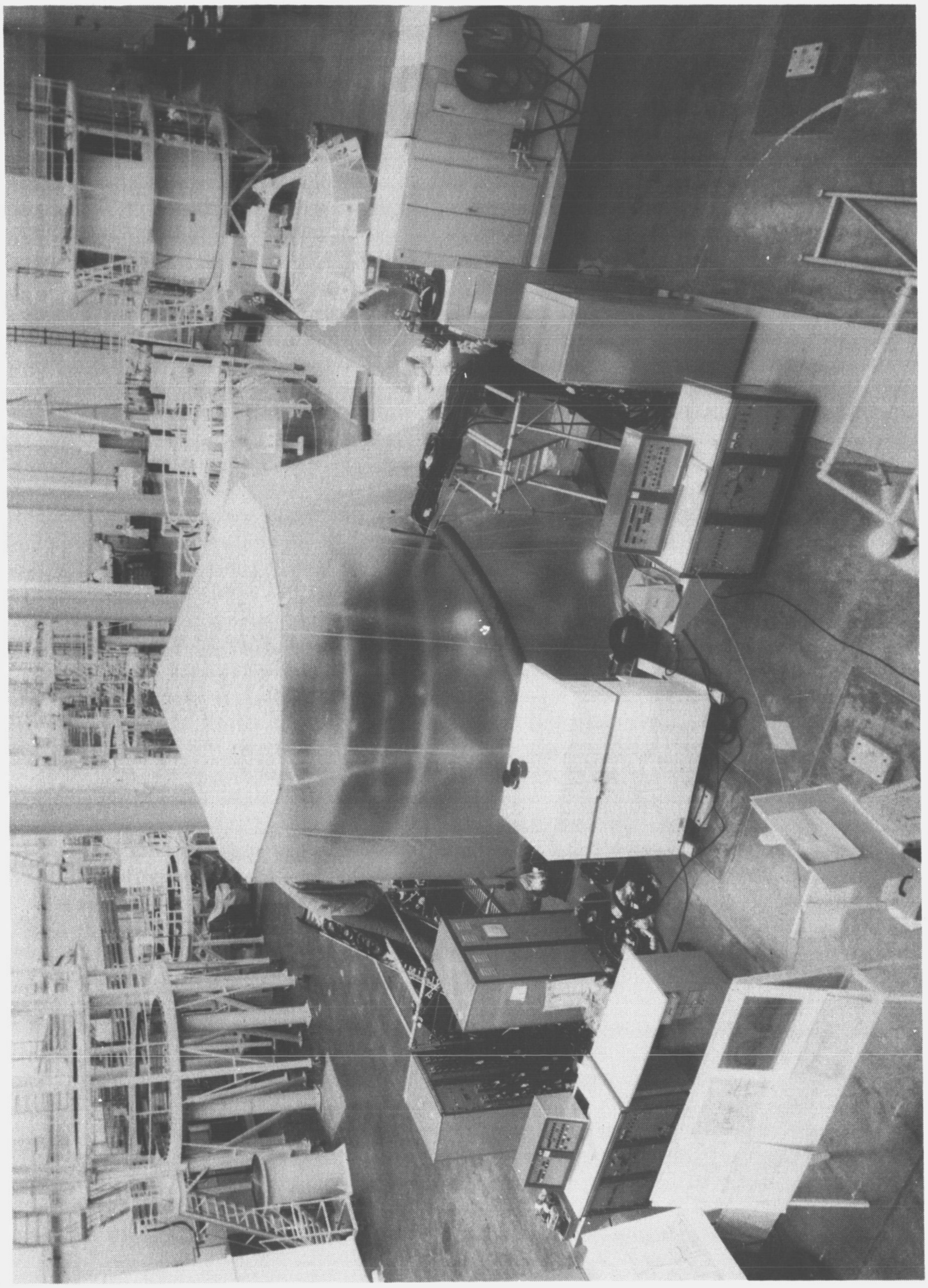


Figure 2. Spacecraft 009 DITMCO Operations



7008-86-215A

Figure 3. Spacecraft 009 Command Module, DITMCO of Lower Equipment Bay Wire Harness

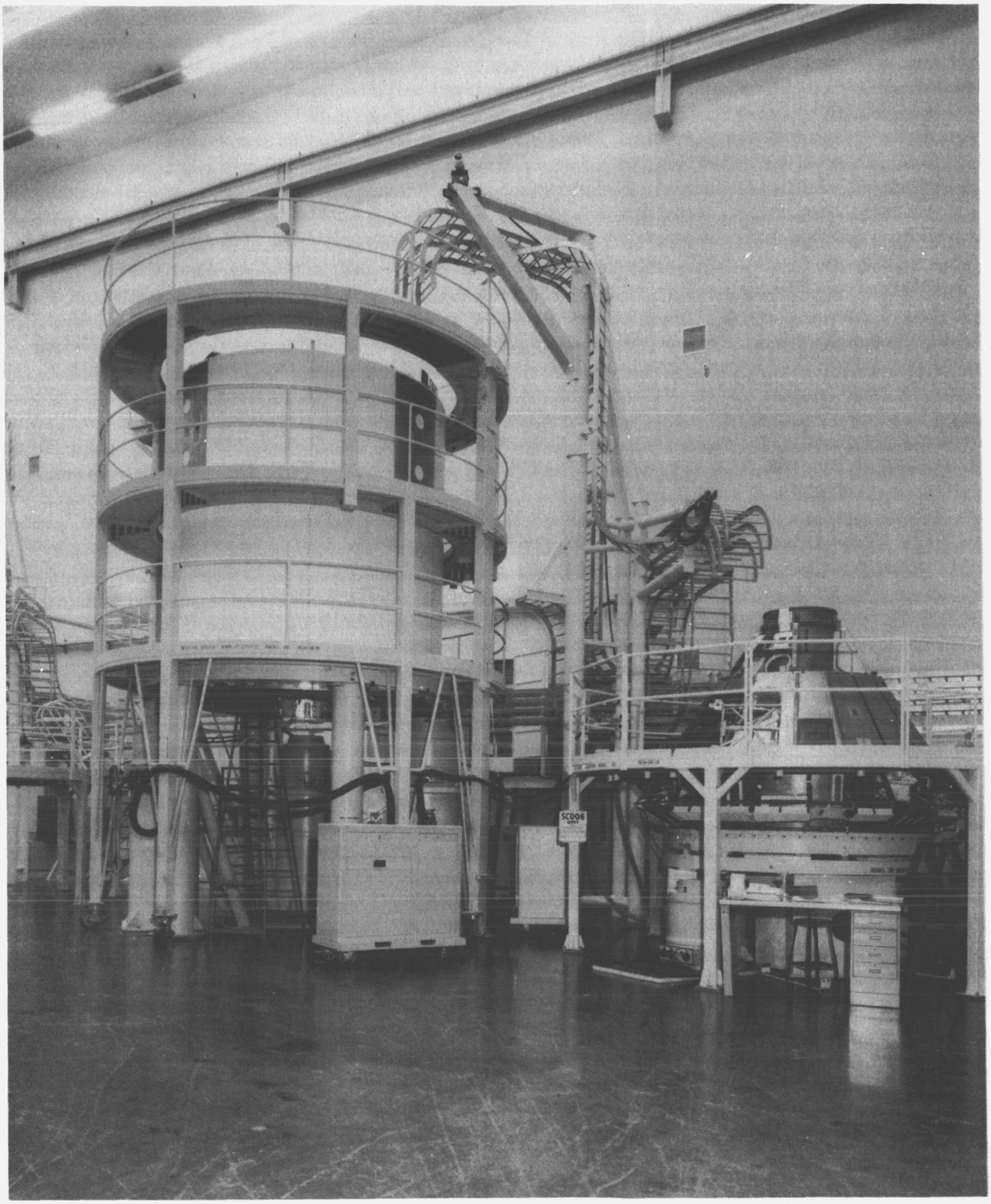


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Figure 4. Spacecraft 006 Quality Verification Vibration Testing

7008-86-207A

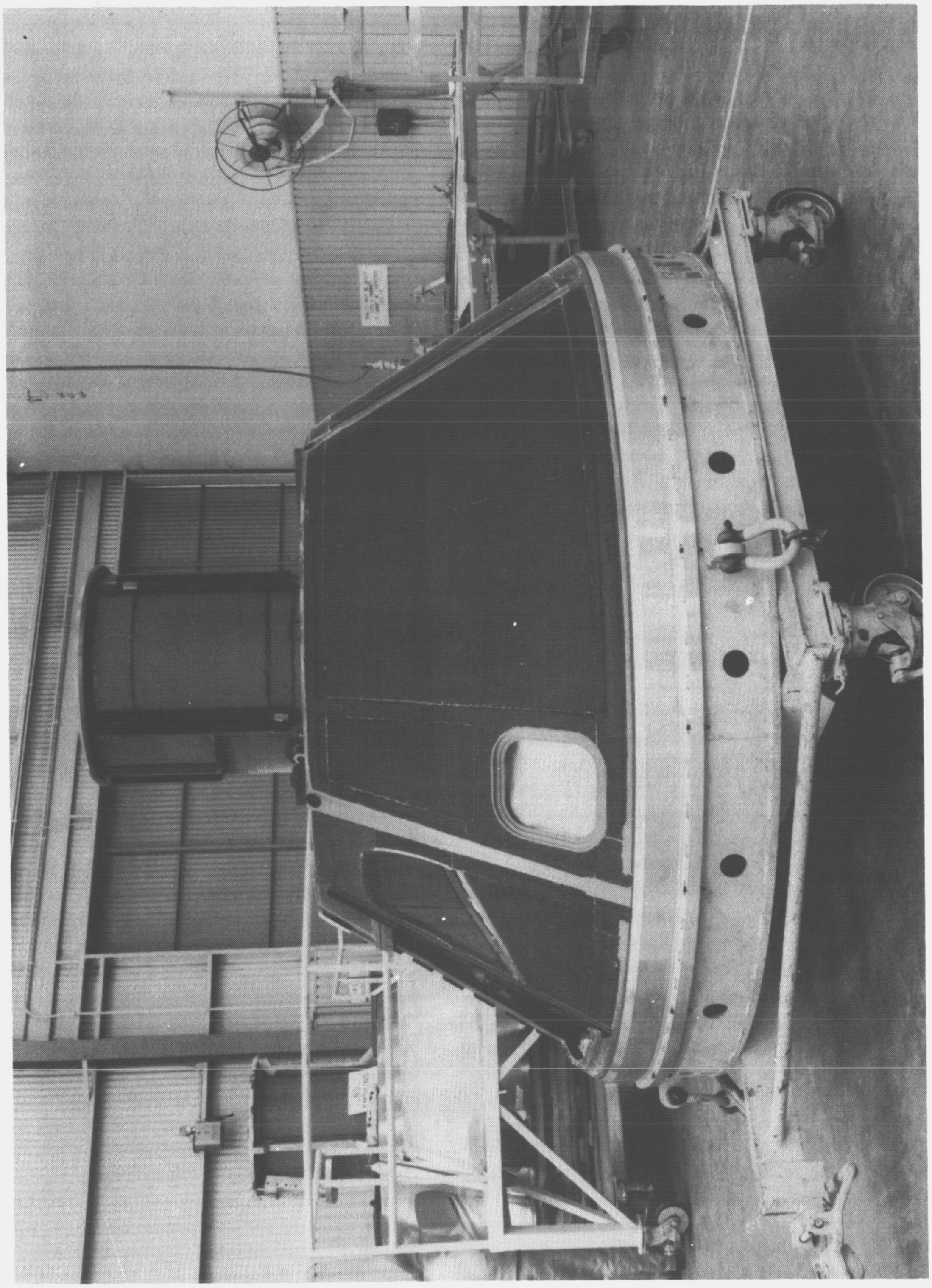

Figure 5. Spacecraft 012 Inner Structure Forward Section After First-Stage Primary Bond

7105 81 99 H

Figure 6. Cleaning Positioner With Command Module Mock-Up

7008-86-206B

Figure 7. Spacecraft 009 Service Module in High-Pressure Test Area

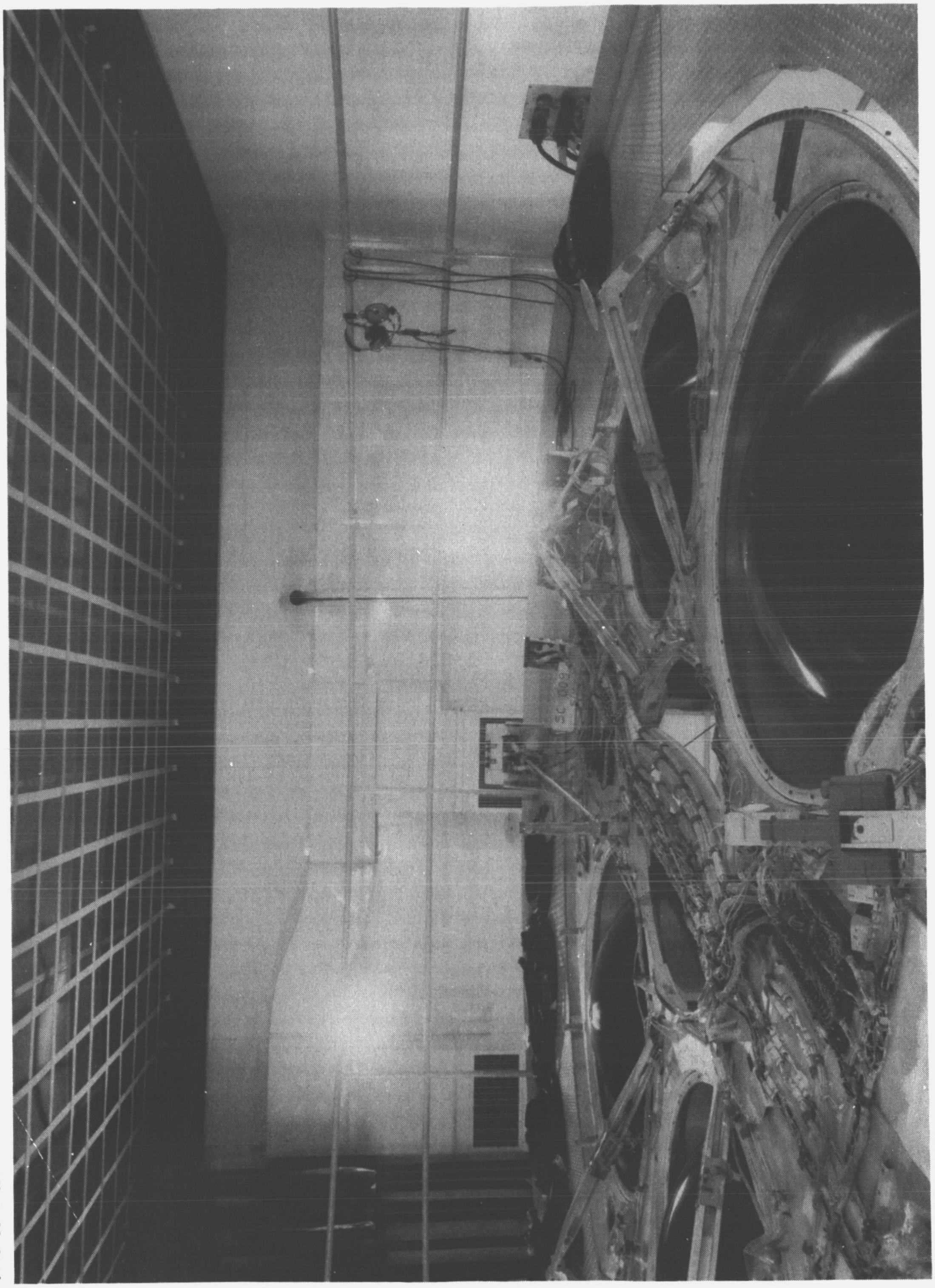

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Figure 8. Top View of Spacecraft 009 Service Module, High-Pressure Test Area

APPENDIX B

S&ID SCHEDULE OF APOLLO MEETINGS AND TRIPS

S&ID Schedule of Apollo Meetings and Trips

Subject	Location	Date	Organization
Design review of acceptance test	Moline, Illinois	Mar 16 to 17	S&ID, Eagle Signal
Stabilization control subsystem checkout procedures	Minneapolis, Minnesota	Mar 16 to 18	S&ID, Honeywell
Establishment of study plan and evaluation criteria, Block II vehicles	Houston, Texas	Mar 17 to 18	S&ID, NASA
Coordination of personnel communications equipment	Houston, Texas	Mar 17 to 19	S&ID, NASA
Review of spares support plan for nuclear particle detection	Palo Alto, California	Mar 17 to 19	S&ID, Philco Western Development Lab
Block II manual vehicle entry control subsystem simulation	Minneapolis, Minnesota	Mar 17 to 26	S&ID, Honeywell
GSE cryogenic storage subsystem integration	White Sands, New Mexico	Mar 21 to 23	S&ID, WSMR
Conduct classes on GSE items	Bethpage, New York	Mar 21 to Apr 1	S&ID, Grumman
Conduct systems training for NASA personnel at MILA	Cocoa Beach, Florida	Mar 21 to Apr 3	S&ID, NASA
Briefing on solution to problems of ACE carry-on removal	Houston, Texas	Mar 22	S&ID, NASA

S&ID Schedule of Apollo Meetings and Trips

Subject	Location	Date	Organization
Review of engine and test cell instrumentation	Tullahoma, Tennessee	Mar 22 to 24	S&ID, AEDC
Conduct training on crew subsystems	Houston, Texas	Mar 22 to 27	S&ID, NASA
Discussion of RCS development program and status support, spacecraft 009	Houston, Texas	Mar 23 to 24	S&ID, NASA
Discussion of test plan for alternate landing impact subsystem for Block II vehicles	El Centro, California	Mar 23 to 25	S&ID, USN
Detailed review of the AMS instructor handbook	Houston, Texas	Mar 24 to 26	S&ID, NASA
Review of entry trajectory units	Cambridge, Massachusetts	Mar 25 to 26	S&ID, MIT
Specification review	Houston, Texas	Mar 28 to 30	S&ID, NASA
Conduct training on electrical power subsystem	Houston, Texas	Mar 28 to Apr 3	S&ID, NASA
Attend NASA management and status review meeting	Houston, Texas	Mar 29 to 30	S&ID, NASA
Review of boilerplate 19 to support boilerplate 22 and Block I qualifications	Houston, Texas	Mar 29 to 30	S&ID, NASA

S&ID Schedule of Apollo Meetings and Trips

Subject	Location	Date	Organization
Crew safety subsystem panel meeting (Block II)	Houston, Texas	Mar 29 to 30	S&ID, NASA
Guidance and navigation program requirements	Houston, Texas	Mar 30 to 31	S&ID, NASA
Discussion of present delivery status difficulties	Wichita, Kansas	Mar 30 to 31	S&ID, Beech
Joint tank program review	Buffalo, New York	Mar 30 to Apr 1	S&ID, Bell
Docking study mechanization	Hampton, Virginia	Mar 30 to Apr 1	S&ID, NASA
Toxicity and material selection criteria negotiation	Houston, Texas	Mar 30 to Apr 1	S&ID, NASA
Checkout panel meeting	Houston Texas	Mar 31 to Apr 2	S&ID, NASA
Technical design review	Tarrytown, New York	Apr 4 to 6	S&ID, Simmonds
Prelaunch operation working group	Bethpage, New York	Apr 4 to 7	S&ID, Grumman
Conduct training of GAEC personnel on common-use GSE	Bethpage, New York	Apr 4 to May 1	S&ID, Grumman
Review of spacecraft 009 heat shield schedules	Lowell, Massachusetts	Apr 5 to 6	S&ID, Avco

S&ID Schedule of Apollo Meetings and Trips

Subject	Location	Date	Organization
Review Block II C & D development program	Cedar Rapids, Iowa	Apr 5 to 6	S&ID, Collins
Direction group meeting, discussion of new design reference mission	Houston, Texas	Apr 5 to 7	S&ID, NASA
Discussion of boilerplate 29 detailed test plans, data and instrumentation requirements	Houston, Texas	Apr 5 to 7	S&ID, NASA
Ground development test working group	Bethpage, New York	Apr 5 to 7	S&ID, Grumman
Conduct training on the sequential subsystem	Houston, Texas	Apr 5 to 10	S&ID, NASA
Review of modified qualification test schedule	Sacramento, California	Apr 6	S&ID, Aerojet
Negotiation on nuclear radiation effect tasks	Houston, Texas	Apr 6 to 7	S&ID, NASA
Review of electrostatic studies	Houston, Texas	Apr 7 to 8	S&ID, NASA
Discussion of repair agreement, review and coordinate supply, and maintenance procedures for control and processing of spares	Boulder, Colorado	Apr 7 to 9	S&ID, Beech

S&ID Schedule of Apollo Meetings and Trips

Subject	Location	Date	Organization
Presentation to NASA of service propulsion subsystem performance for spacecraft 009	Houston, Texas	Apr 8 to 9	S&ID, NASA
Resolution of interface problems between heat shield side hatch and environmental chamber umbilical	Huntsville, Alabama	Apr 12 to 13	S&ID, NASA
Presentation of technical data package for spacecraft 009	Houston, Texas	Apr 12 to 13	S&ID, NASA
Twelfth flight mechanics dynamic and guidance and control panel	Houston, Texas	Apr 12 to 13	S&ID, NASA
Monthly NASA-NAA site activation meeting	Houston, Texas	Apr 12 to 14	S&ID, NASA
Coordination meeting on program review and EMI test evaluation	Lima, Ohio	Apr 12 to 15	S&ID, Westinghouse
Mission simulator and LEM mission simulator meeting	Bethpage, New York	Apr 12 to 15	S&ID, Grumman
Conduct training on structure and mechanical subsystem	Houston, Texas	Apr 12 to 17	S&ID, NASA
Conduct training on the telecommunication subsystem	Houston, Texas	Apr 12 to 17	S&ID, NASA
Review of technical status of Apollo antennas	Houston, Texas	Apr 13 to 15	S&ID, NASA

S&ID Schedule of Apollo Meetings and Trips

Subject	Location	Date	Organization
Coordination of repair of TV camera and bench maintenance equipment at MSC	Princeton, New Jersey	Apr 13 to 16	S&ID, RCA
Review of qualification test program, establishment of supplemental development tests	San Carlos, California	Apr 14 to 16	S&ID, Pelmec
Review of engine performance derived from Phase II simulated altitude test program	Houston, Texas	Apr 15 to 16	S&ID, NASA